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Activation of Air and Utilities in the National Ignition Facility

Hesham Khater, Bertram Pohl, Sandra Brererton

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Activation of Air and Utilities in the National Ignition Facility

**Presentation to
The 2010 Joint Topical Meeting of the Nevada Section
of the American Nuclear Society
April 19, 2010**

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Hesham Khater, Bertram Pohl and Sandra Brereton

Lawrence Livermore National Laboratory

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Outline

- I. Introduction to the NIF**
- II. The NIF facility modeling**
- III. Air activation**
- IV. Activation of utilities**
- V. Summary**

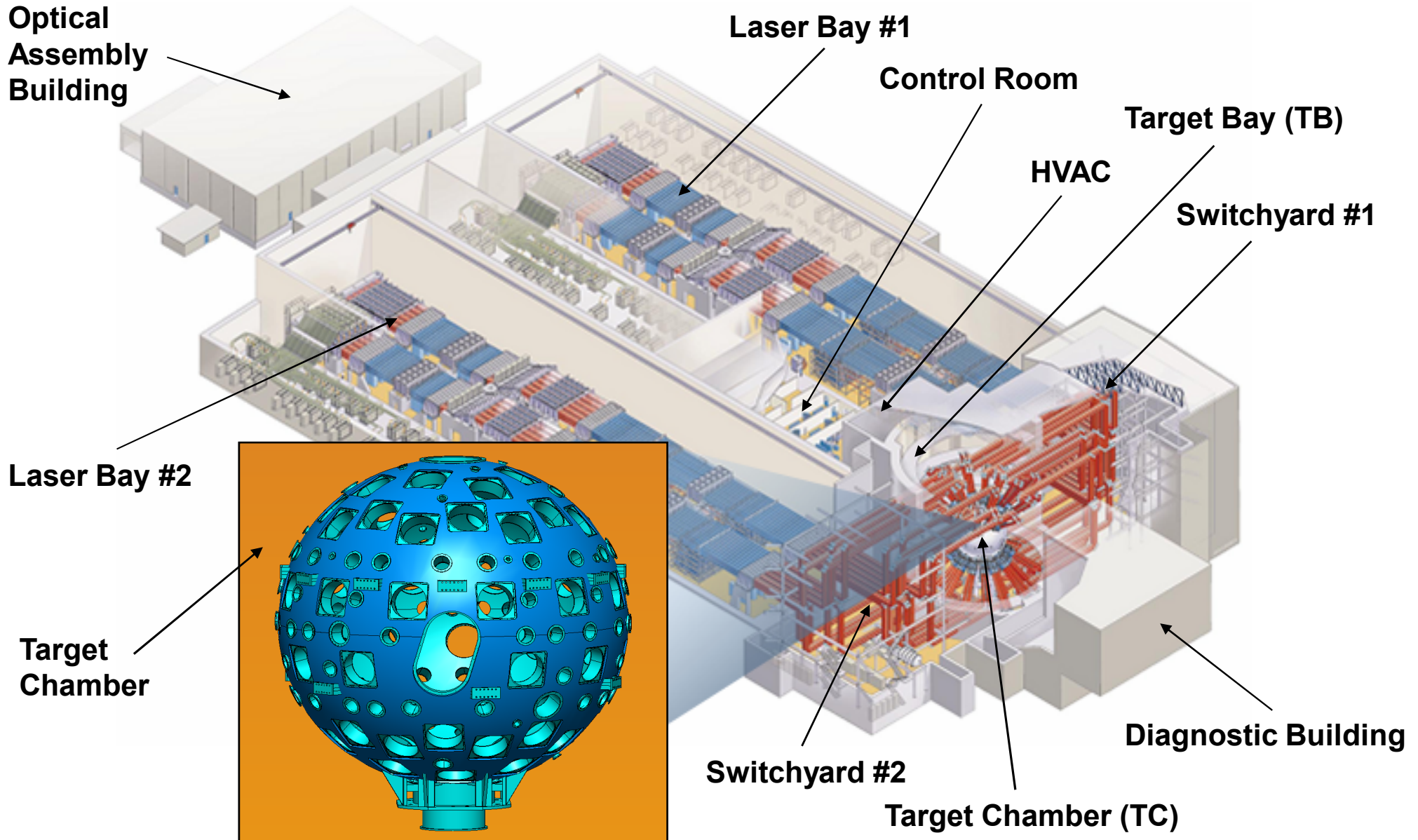
Introduction

- Detailed 3-D modeling of the NIF facility is developed to accurately simulate the radiation environment within the NIF
- Neutrons streaming outside the NIF Target Chamber will activate the air present inside the Target Bay and the Ar gas inside the laser tubes
- Smaller levels of activity are also generated in the Switchyard air and in the Ar portion of the SY laser beam path
- The impact of neutron activation of utilities located inside the Target Bay is analyzed for variety of shot types
- The impact of activating TB utilities on dose received by maintenance personnel post-shot is analyzed

192 Pulsed Laser Beams
Energy 1.8 MJ 3ω
Power 500 TW

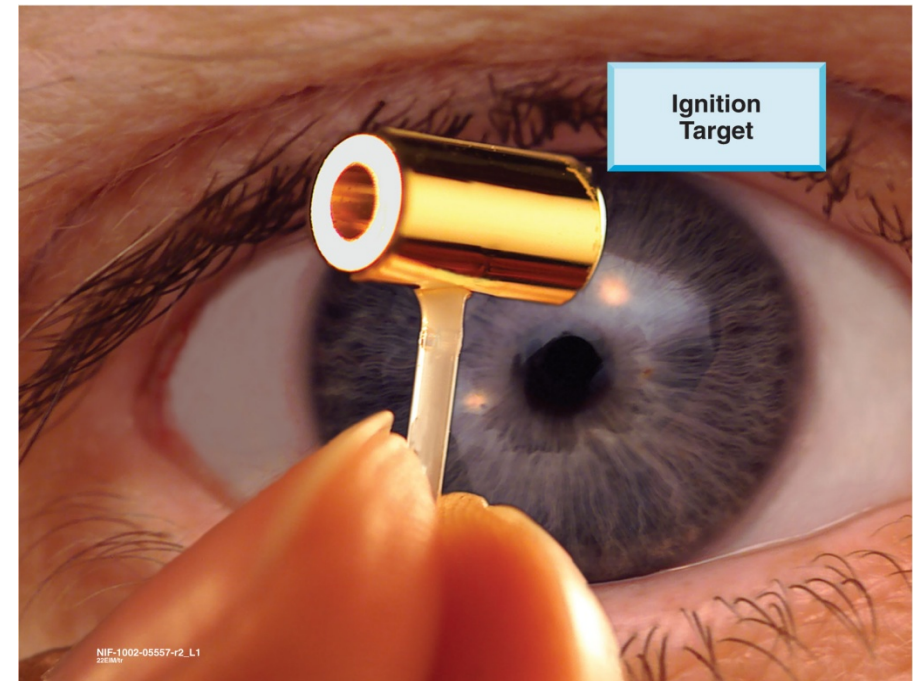
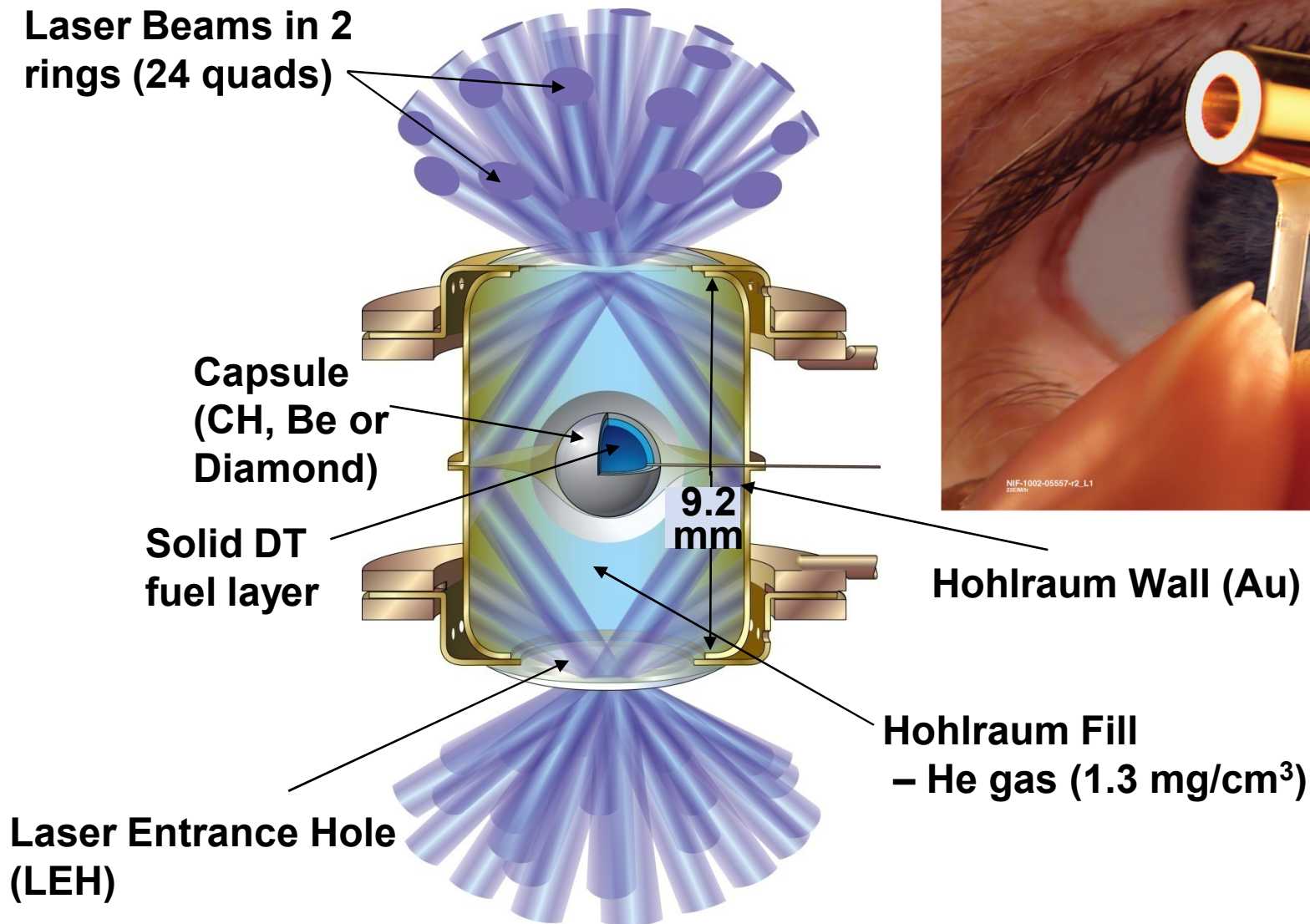


NIF Layout





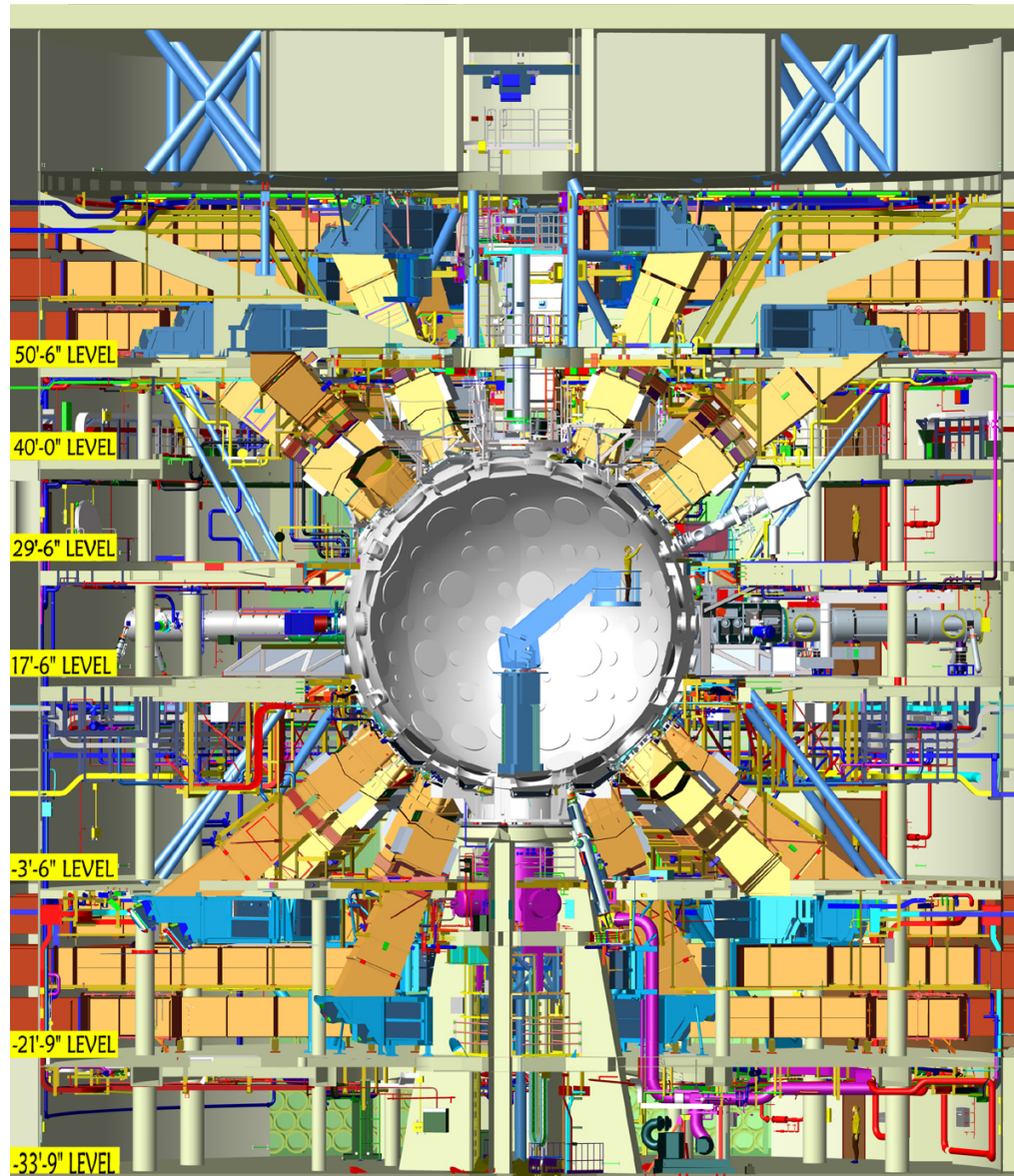
Ignition point design target



Features of the current NIF facility model

- Based on the facility as-built drawings
- 10-cm-thick Al Target Chamber (TC) wall surrounded by 40-cm of borated concrete
- 6'-thick concrete Target Bay (TB) wall
- 3'-3"-thick concrete Switchyard walls
- All Target Chamber, Target Bay and Switchyard wall penetrations are modeled
- Diagnostics and Direct Drive ports are only covered with ~ 2" aluminum
- Final Optics Assemblies (FOAs) are modeled

Sectional view of the Target Bay



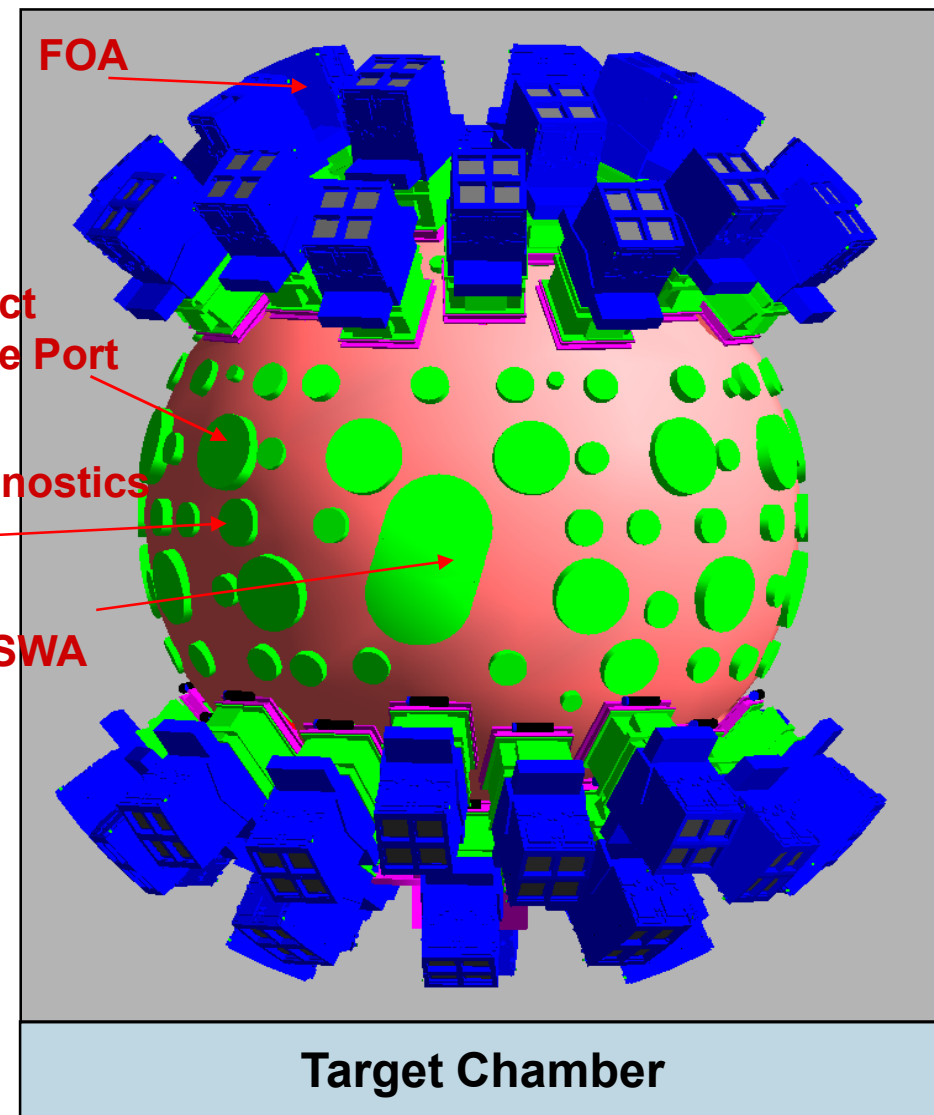
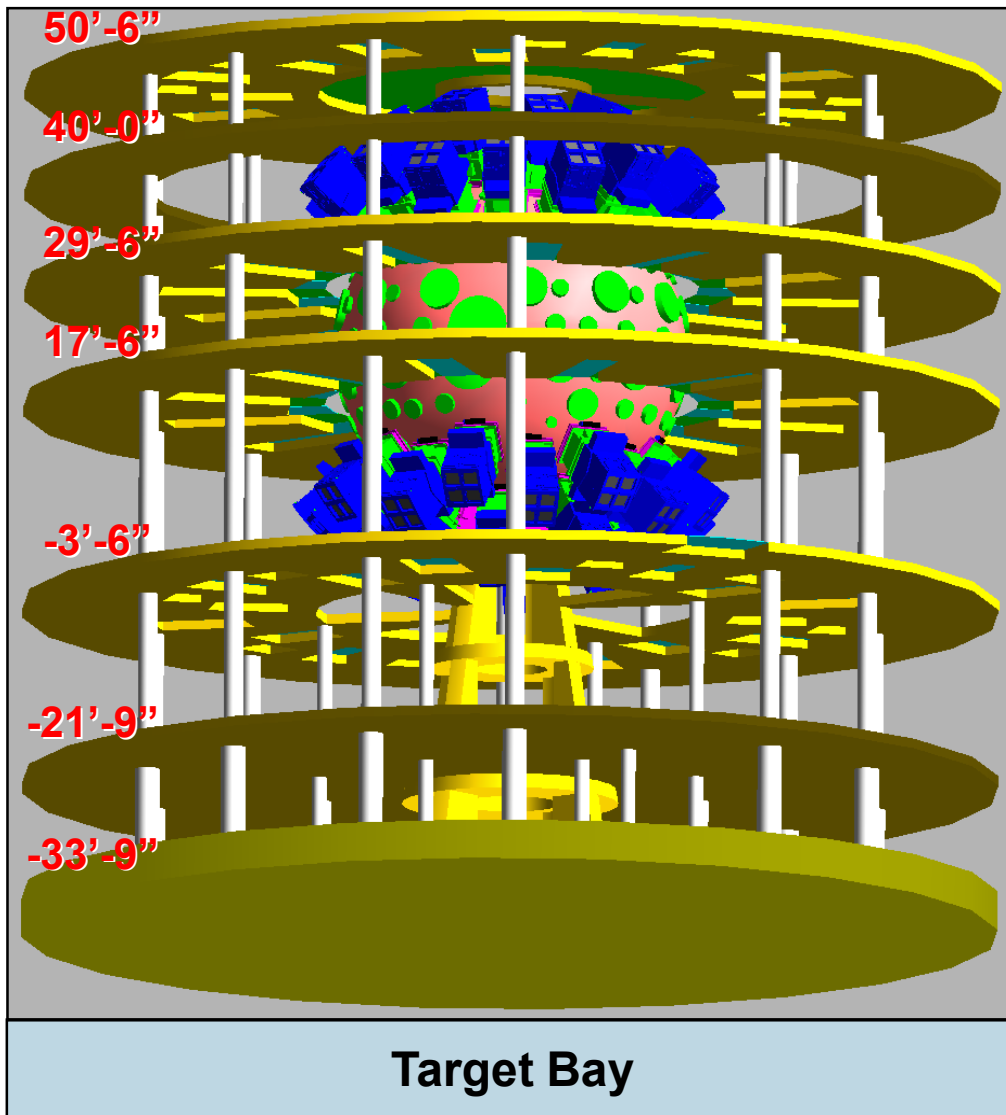
Target Bay
Section View

May 2009

NIF
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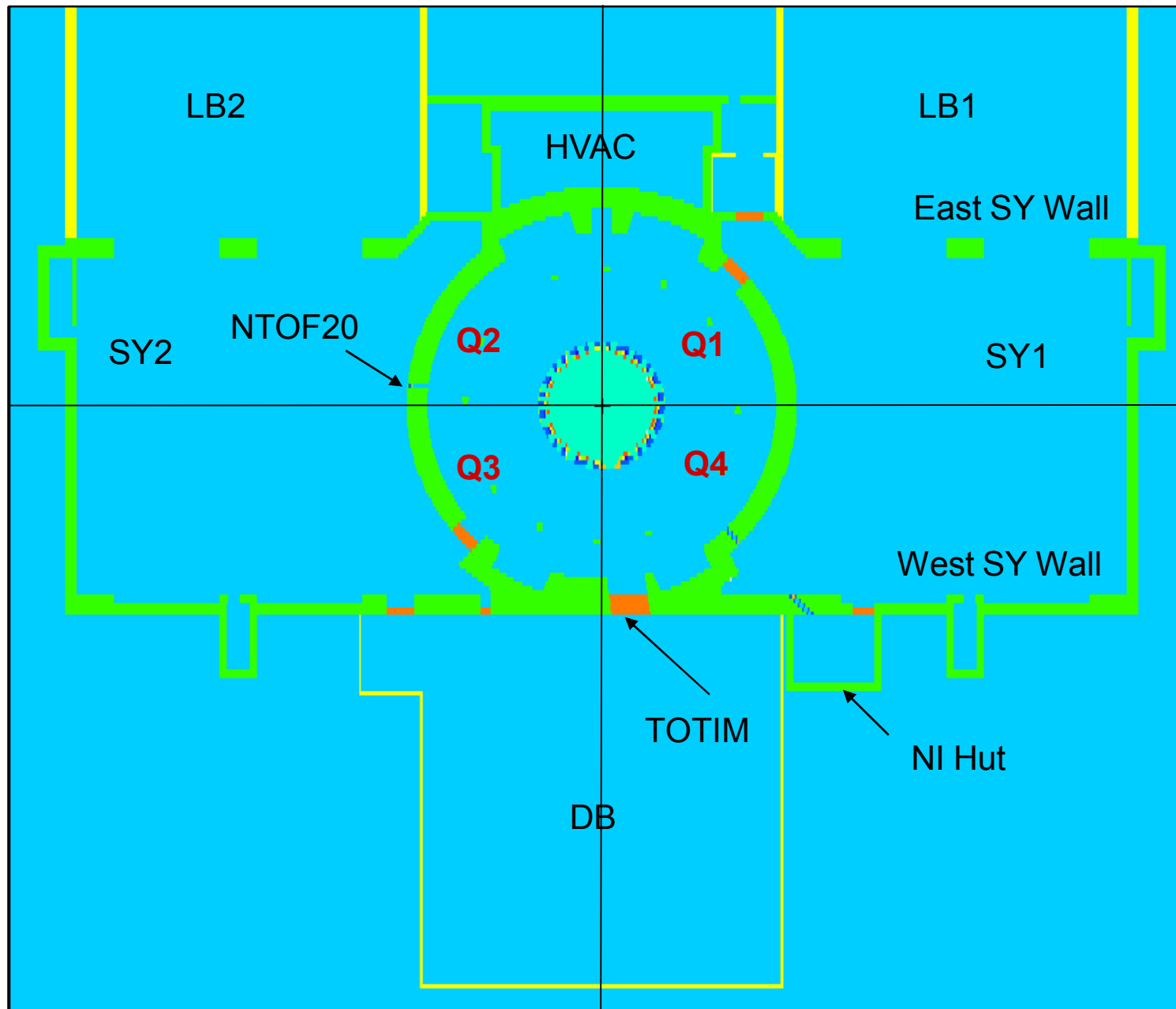
MCNP models



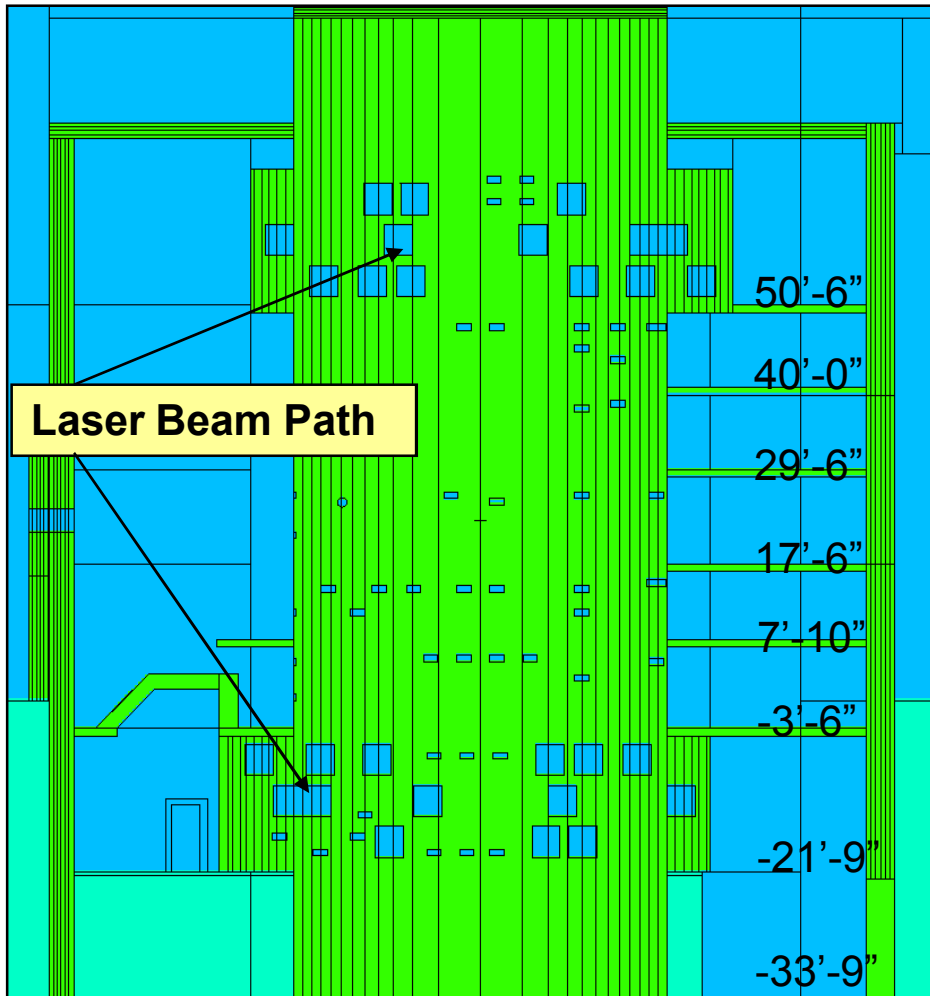
Radiation pathways

- **Target Chamber penetrations**
 - 48 indirect-drive beam ports (FOAs)
 - 24 direct-drive beam ports
 - 120 diagnostic ports
- **Target Bay wall penetrations**
 - Laser beam path in TB walls
 - 175 utility penetrations (38% shielded)
 - 10 diagnostic penetrations
- **West Switchyard wall penetrations**
 - 18 utility penetrations
 - 2 diagnostic penetrations
- **East Switchyard wall penetrations**
 - 26 utility penetrations
 - Laser beam tubes at the 17' 6" level
- **Doors**
 - Target Bay: 20 primary (19 shielded)
 - Switchyards: 32 secondary (27 shielded)

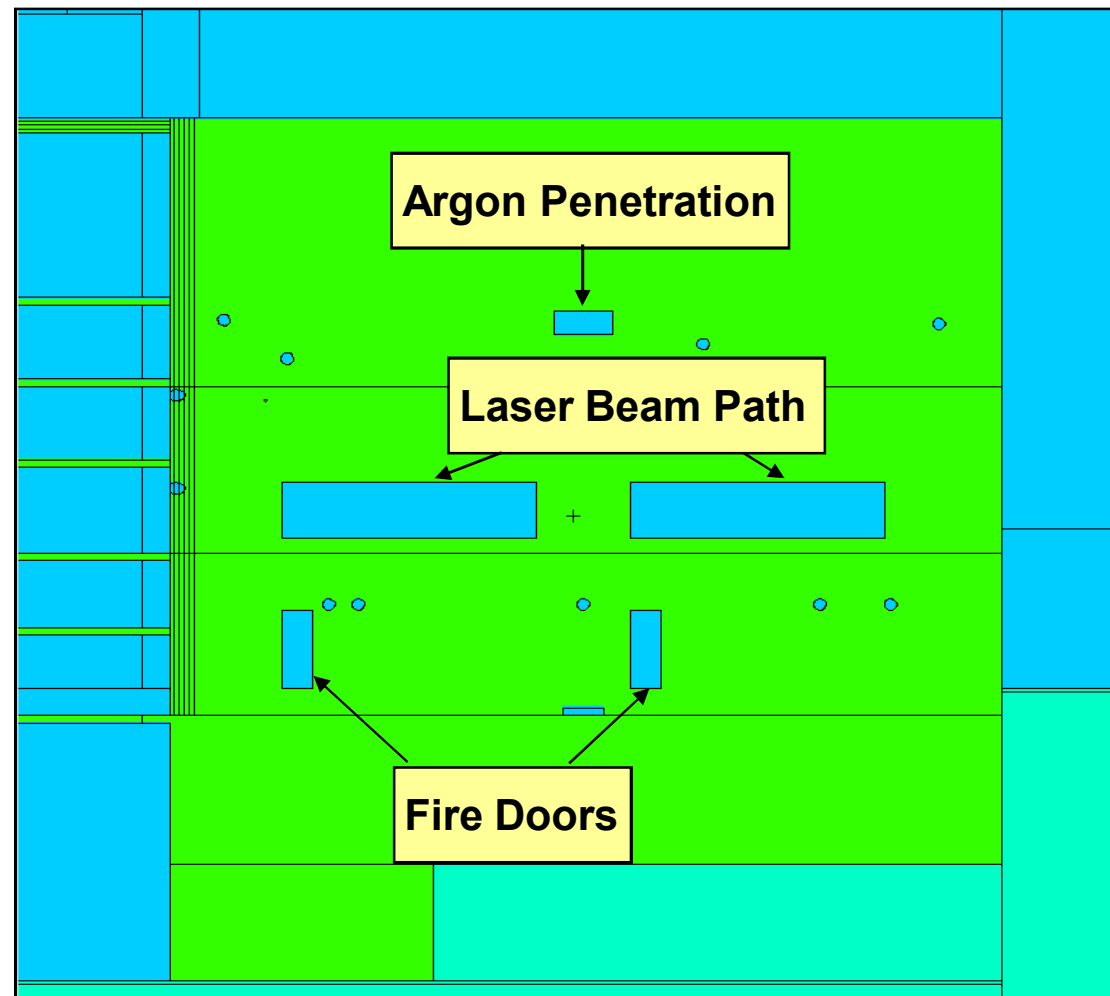
Horizontal view of TB at TCC



Vertical view of Q1 and Q4 of TB wall

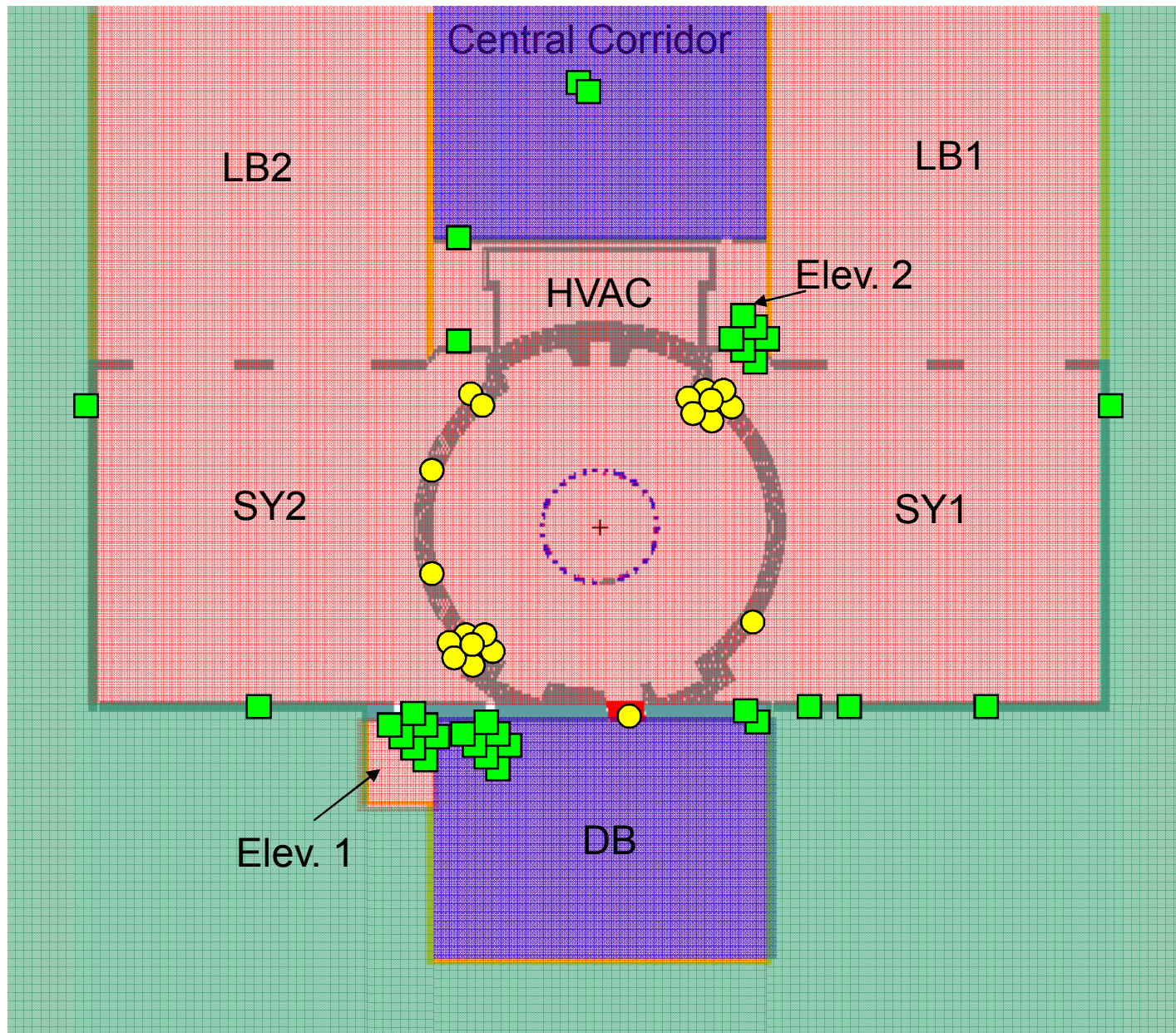


Vertical View of Q1 and Q4 of TB Wall



Vertical View of East Wall of SY1

Summary of shield door locations



- Exclusion areas
- Normally occupied areas within the facility
→ 1/3 occupancy
- Occasionally occupied areas outside the facility
→ 1/16 occupancy
- Primary door location
- Secondary door location

Radiation environment during different phases of the NIF operation

- **Phase I: X-rays due to 3ω laser interaction with target (up to 1.8 MJ of laser energy)**
- **Phase II: 2.45 MeV neutrons during D-D shots (up to 12 J or $1e13$ neutrons per shot)**
- **Phase III: 14.1 MeV neutrons during THD or D-T shots (up to $1e16$ neutrons per shot)**
- **Phase IV: 14.1 MeV neutrons during D-T shots (up to 20 MJ or $7.1e18$ neutrons per shot and ≤ 1200 MJ per year)**

Simulation approach/assumptions

- Radiation transport simulations performed using the MCNP code
- Particle splitting and Russian roulette are used throughout the geometry
- Material activation and gamma decay data are calculated with the ALARA activation code
- FENDL cross section and decay data libraries
- ICRP-74 fluence to effective dose conversion factors

Post-shot air activation

- High yield (20 MJ) shots result in activation of Target Bay air as well as Ar gas in the laser beam path
- Much lower levels of activation (by ~ 3 orders of magnitude) occur in the Switchyard air and Ar in the laser tubes
- Argon normally leaks from the laser beam path at a very low rate of about 30-35 cfm (for the entire facility ~ 160,000 ft³)
- Air re-circulates through air handlers located at different locations inside and outside the facility
- The most activated air from the Target Bay re-circulates through the air handlers located in two rooms (MER) at the 28'-6" and 47'-6" floor levels (in the central corridor)

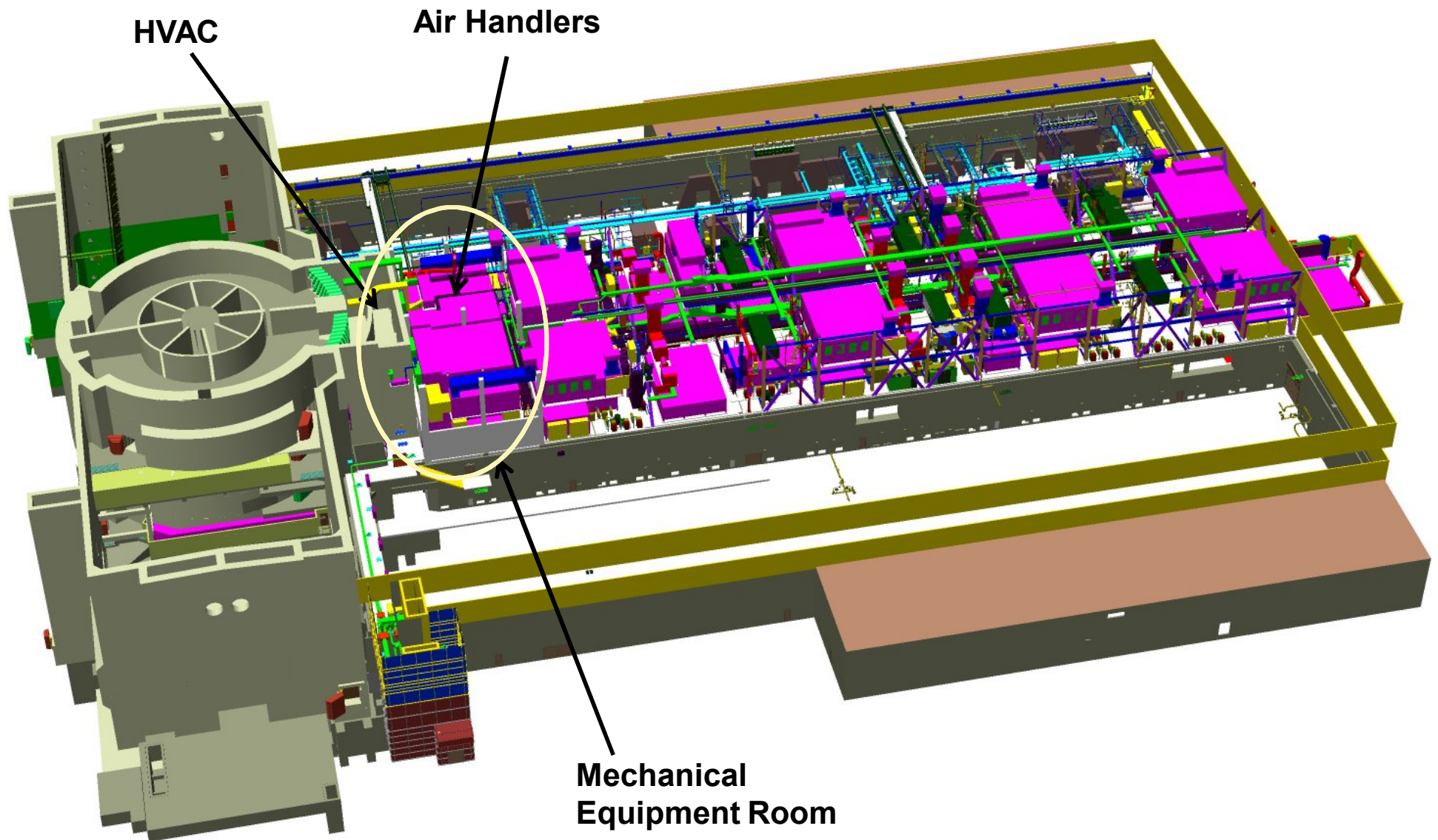
Radioactive inventory in the Target Bay air following 20 MJ shot

Nuclide	Half-life	Air Activity (Ci)	Ar Activity (Ci)
H-3	12.32 yr	5.8e-5	5.3e-8
C-14	5715 yr	1.6e-5	1.8e-8
N-13	9.97 min	5.43	4.8e-3
N-16	7.13 sec	857	0.75
S-37	5.05 min	0.13	0.87
Cl-40	1.38 min	0.45	3.2
Ar-41	1.83 hr	0.68	6.05

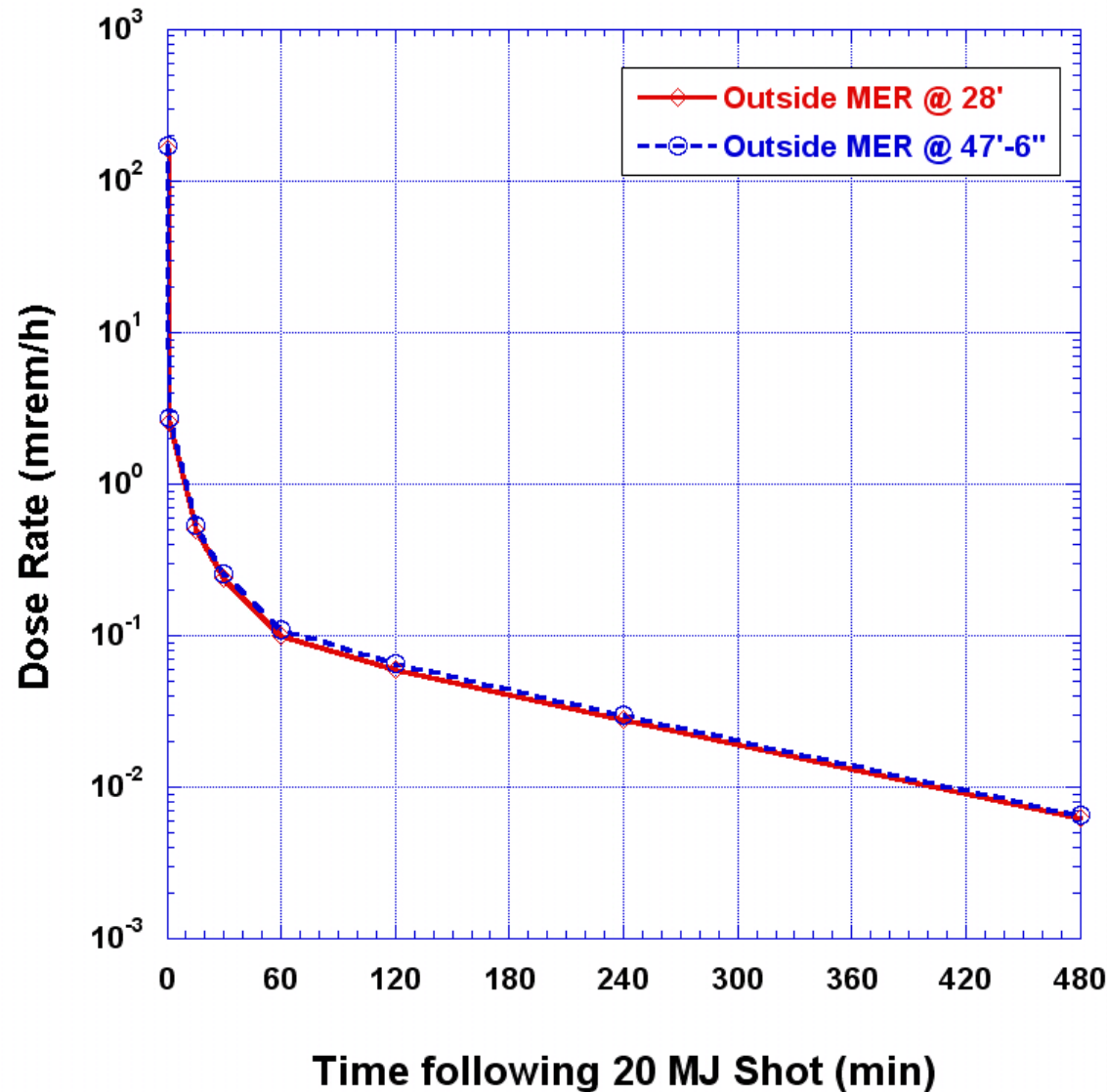
Confinement mode

- During confinement mode, the Target Bay pressure is negative to the adjacent spaces and the outside of the facility
- The HVAC system re-circulates up to 360,000 cfm of the Target Bay air
- Target Bay exhaust flow rate is limited to $< 1\%$ of air volume/min (about 9000 cfm)
- Allows for significant decay of short-lived nuclides and minimizes radioactive release through the stack
- All exhaust goes through the Environmental Protection System stack
- Confinement mode to remain in effect for at least 2 hours after 20 MJ shot to allow for significant decay of isotopes

Target Bay Air Handlers



Dose rates outside Mechanical Equipment Room (MER)

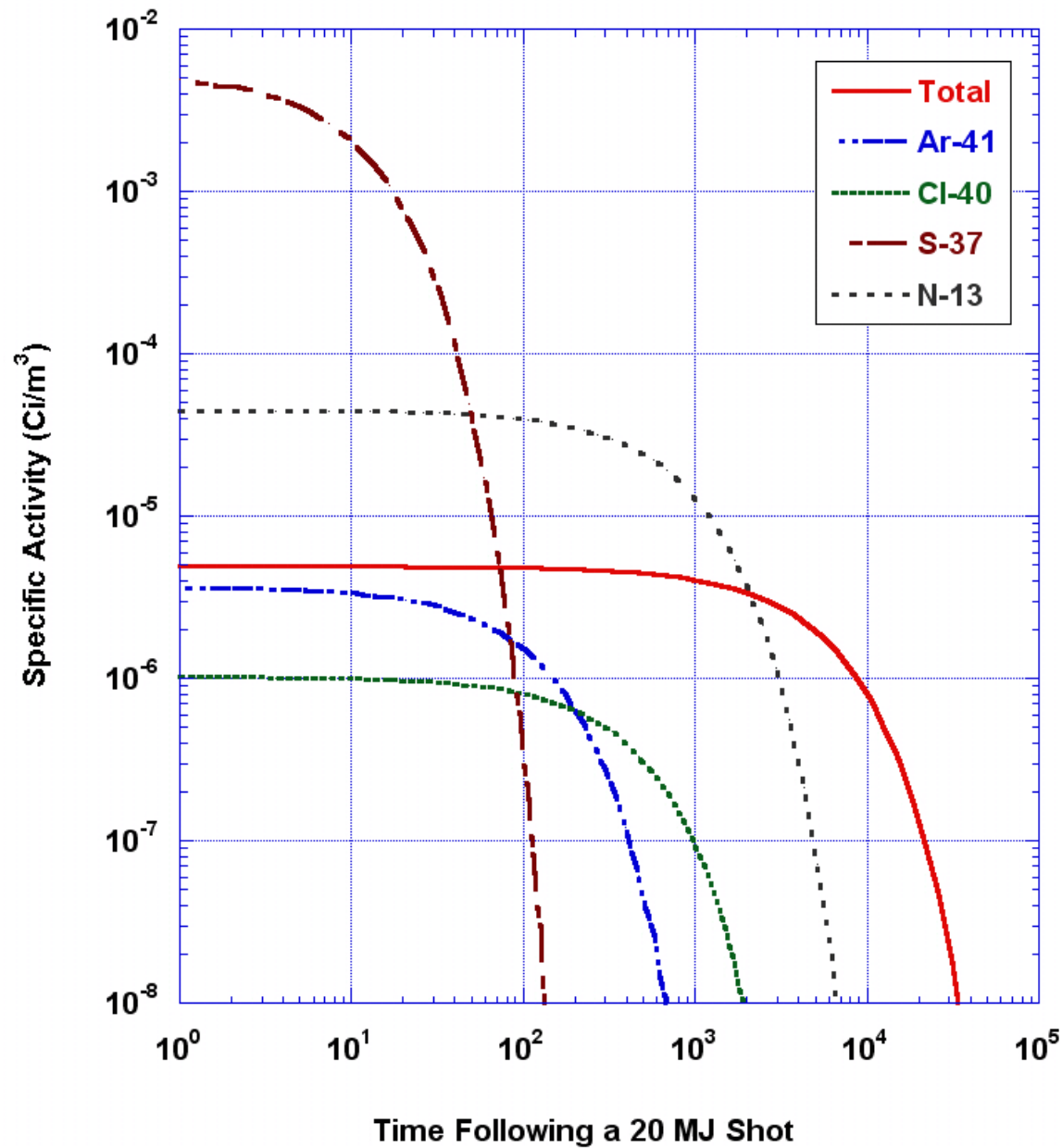


Integrated dose over 8-h period is ~ 2 mrem

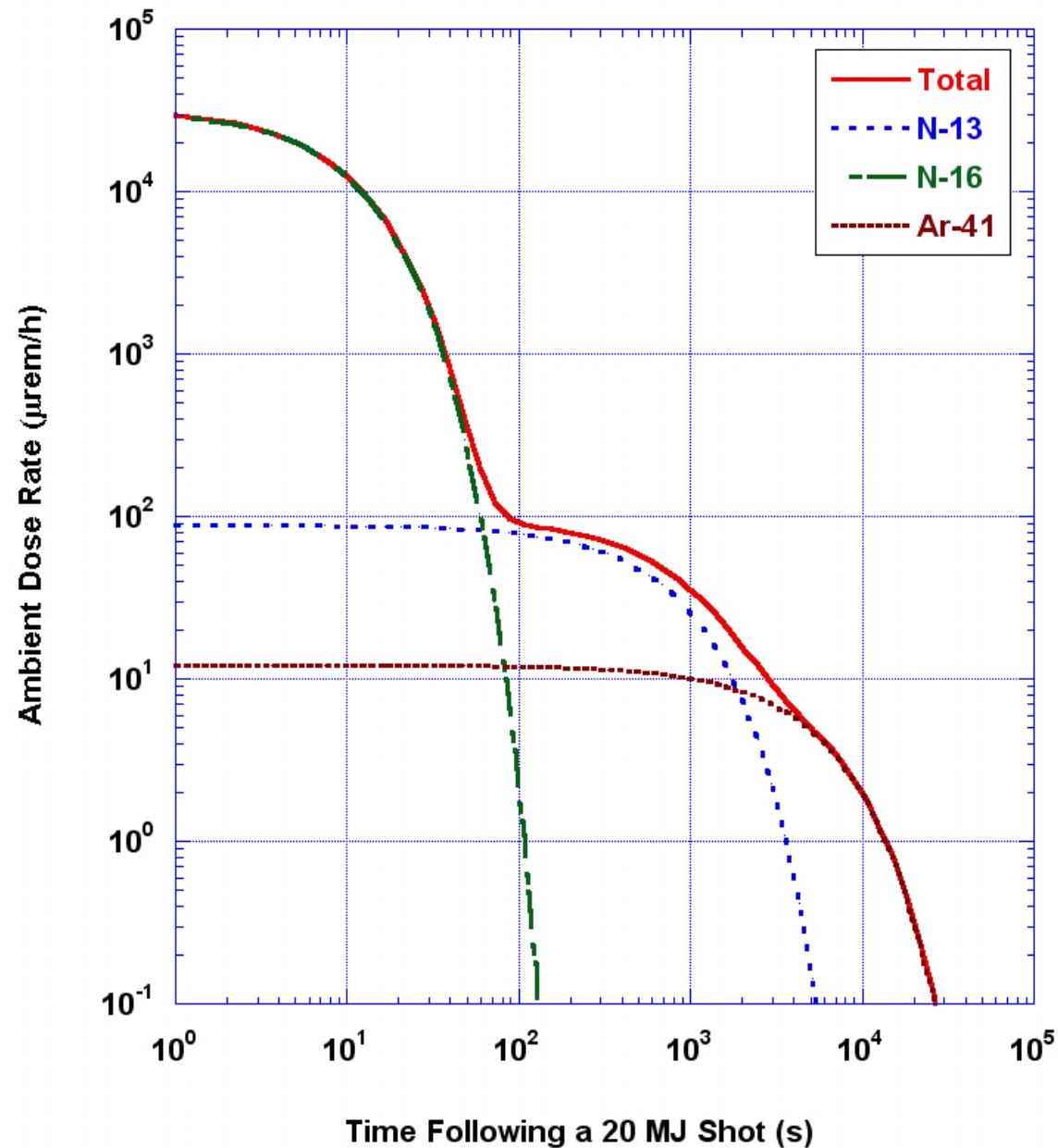
Stack release parameters

- Volume of activated air in the Target Bay = 905,810 ft³
- Confinement flow rate from Target Bay = 5000 cfm
- Confinement flow rate from Diagnostics Building = 21000 cfm
- Total flow rate = 26000 cfm
- Transient distance in stack = 12.5 m
- Air Velocity = 4.8 m/sec
- Transient time in stack = 2.6 sec

Activities released through the stack



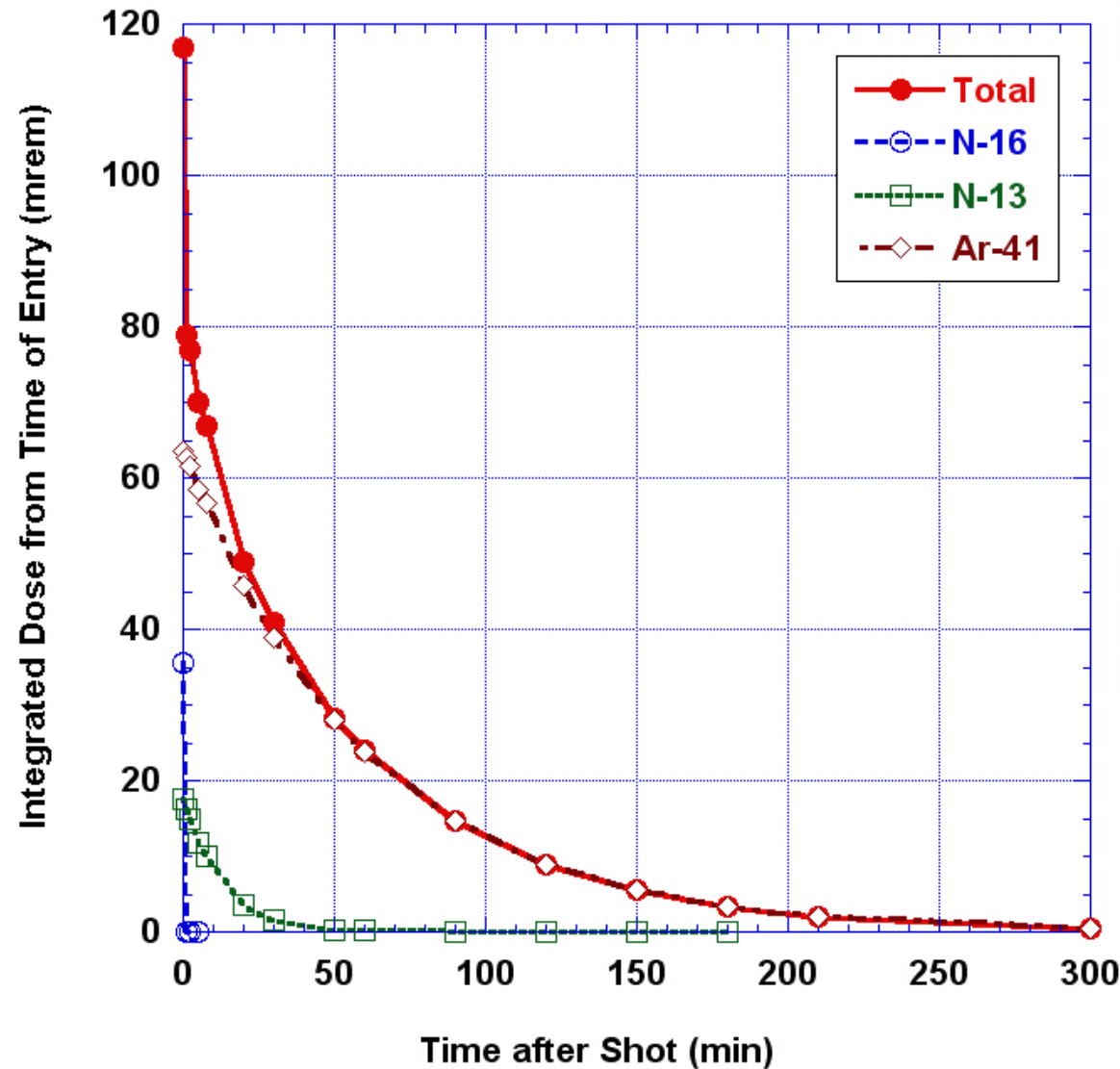
Dose rate in the vicinity of the stack



Immersion dose assumption

- **Conservatively estimate the dose due to activated air inside the Target Bay**
- **Semi-infinite cloud**
- **Target Bay exhaust rate of 1% of air volume/min**
- **10CFR835 immersion dose conversion factors**
- **20 MJ shot**

Target Bay immersion dose



Maximum immersion dose of 3 mrem if access is not allowed during the first 3 hours following a 20 MJ shot

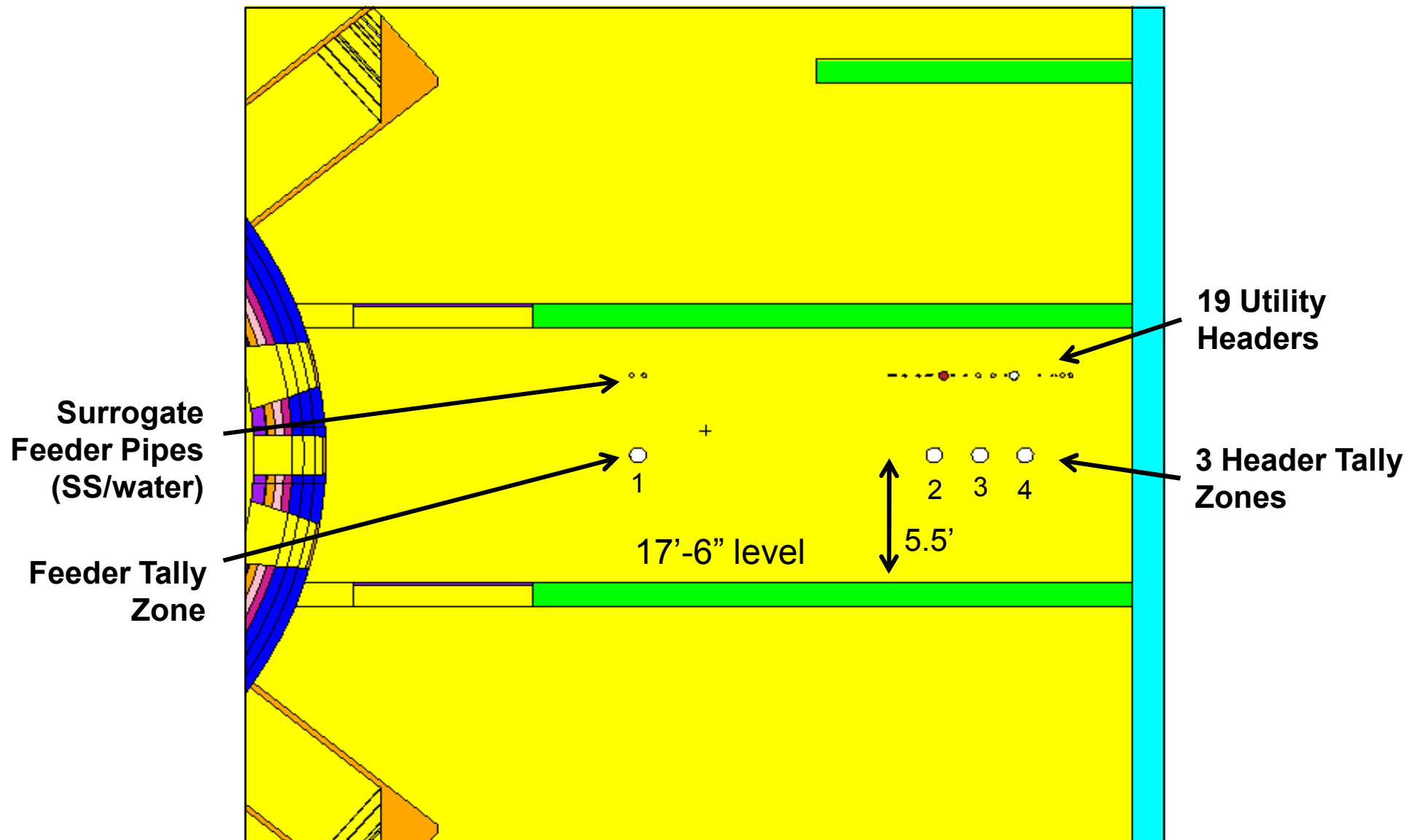
Activation of Target Bay utilities

- **Level 17'-6"** of the NIF Target Bay is serviced by a large array of utilities brought in on suspended pipes that circle outside the Target Chamber and close to the ceiling
- **The area with the greatest density of piping was added to the Target Bay model**
- **19 utility pipes were identified with 9 types of material specifications**
- **Two additional 2" water pipes were added to the Target Bay model to simulate feeder pipes servicing various apparatuses surrounding the Target Chamber**

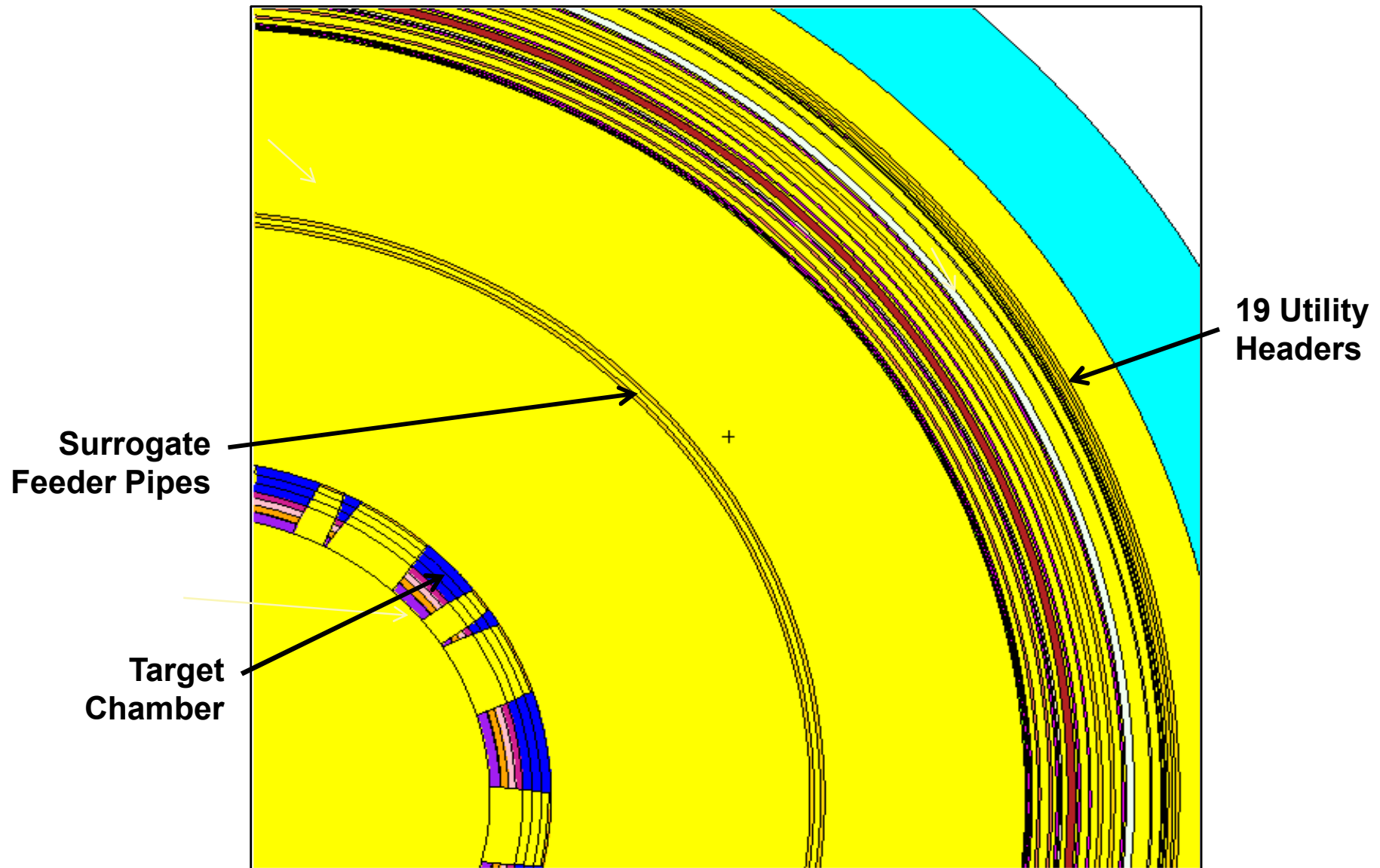
List of major utilities at the 17'-6" floor level

Utility Name	Pipe Material	Content	Nominal Size (inches)
EMT Conduit	Mild Steel	Copper Wires	0.75
Rigid Conduit	Mild Steel	Copper Wires	0.75
Rigid Conduit	Mild Steel	Copper Wires	0.75
Tempered Water - s	Copper	Water	1.50
Tempered Water - r	Copper	Water	1.50
Rigid Conduit	Mild Steel	Copper Wires	1.00
Compressed Air	Stainless Steel	Air 7 atm	1.00
Diagnostics Vacuum	Stainless Steel	Vacuum	4.00
Rigid Conduit	Mild Steel	Copper Wires	1.00
Rigid Conduit	Mild Steel	Copper Wires	1.00
FOA Water - s	Stainless Steel	Water	2.00
FOA Water - r	Stainless Steel	Water	2.00
Rigid Conduit	Mild Steel	Copper Wires	1.00
Fire Suppression Water	Black Steel	Water	4.00
Compressed Air	Copper	Air 7 atm	1.00
Compressed Helium - s	Copper	Air 10 atm	0.75
Compressed Helium - r	Copper	Air 10 atm	0.75
FOA Water - s	Stainless Steel	Water	2.00
FOA Water - r	Stainless Steel	Water	2.00

Vertical view of the Target Bay model @17'-6"



Horizontal view of the Target Bay model @ 17'-6"



Activation schedule

Shot Type	Neutrons per Shot	Schedule
D-D	10^{13}	4 shots per day 50 days Total: 200 shots
THD	10^{16}	2 shots per day 25 days Total: 50 shots
D-T	7.1×10^{18}	60 shots per year

Effective dose rates (mrem/h) due to utilities at the 17'-6" level (D-D shots)

Time Following Last shot	Below Surrogate Feeder Pipes (1)	Below Utility Headers (2)	Below Utility Headers (3)	Below Utility Headers (4)
10 min	2.0e-4	3.0e-4	3.1e-4	3.0e-4
1 hour	1.5e-4	2.1e-4	2.2e-4	2.1e-4
1 day	4.6e-6	1.1e-5	1.1e-5	9.1e-6

Activation of Target Bay utilities is negligible following D-D shots

Effective dose rates (mrem/h) due to utilities at the 17'-6" level (THD shots)

Time Following Last shot	Below Surrogate Feeder Pipes (1)	Below Utility Headers (2)	Below Utility Headers (3)	Below Utility Headers (4)
10 min	0.13	0.2	0.2	0.2
1 hour	0.1	0.13	0.13	0.13
1 day	2.1e-3	3.9e-4	4.4e-3	4.0e-3

Activation of Target Bay utilities is small after 1 hour wait-period following THD shots

Effective dose rates (mrem/h) due to utilities at the 17'-6" level (D-T shots)

Time Following Last shot	Below Surrogate Feeder Pipes (1)	Below Utility Headers (2)	Below Utility Headers (3)	Below Utility Headers (4)
10 min	94.1	142.1	147.3	139.3
1 hour	63.8	86.6	92.4	89.1
1 day	0.8	1.7	1.6	1.4
5 days	0.1	0.1	0.1	0.1

Insignificant contribution from utilities after 5 day wait-period following 20 MJ shots

Contact dose rates (mrem/h) due to different utilities (D-T shots)

Time Following Last shot	10 min	1 hour	1 day	5 days
Electrical Conduit	403	148	9.8	0.3
Tempered Water	618	198	19.8	0.3
Compressed Air	661	400	7.6	0.6
Diagnostics Vacuum	821	550	6.2	0.9
FOA Water	859	621	4.9	0.6
Fire Suppr. Water	929	614	4.9	0.5
Compressed Helium	434	251	6.3	0.3

Small contact dose rates are expected after 5 day wait-period following 20 MJ shots

Activation of fire extinguishers

- The fire extinguishers are the dry chemical type Ansul SY 1014 or equivalent
- Information published for the SENTRY 10 SY-1014 type ABC was used to model the 4 extinguishers evaluated in this analysis
- The extinguishers are essentially pressurized carbon steel cylindrical casings filled with powdered mono-Ammonium Phosphate
- The fire extinguishers were modeled on opposite sides of the Target Bay wall near the doors on the 17'-6" and 29'-6" levels

Effective dose rates (mrem/h) near fire extinguishers

Time Following Last Shot	Level 17'-6" (A)	Level 17'-6" (B)	Level 29'-6" (A)	Level 29'-6" (B)
10 min	76.7	81.2	39.5	39.1
1 hour	43.5	46.0	27.5	29.0
1 day	0.16	0.17	0.09	0.1
5 days	0.07	0.075	0.038	0.04

Dose rates are calculated following sixty 20 MJ shots

Summary

- The current NIF facility model includes all important features of the Target Chamber, shielding system, and building configuration
- Flow of activated air from the Target Bay is controlled by the HVAC system
- The amount of activated Target Bay air released through the stack is very small and does not pose significant hazard to personnel or the environment
- Activation of Switchyard air is negligible
- Activation of Target Bay utilities result in a manageable dose rate environment post high yield (20 MJ) shots
- The levels of activation generated in air and utilities during D-D and THD shots are small and do not impact work planning post shots



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